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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE THE MILNER QUADRANGLE, ROUTT COUNTY, COLORADO

[Report includes 17 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

By

DAMES & MOORE

DENVER, COLORADO

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INTRODUCTION

Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Milner quadrangle, Routt County, Colorado. This report was compiled to support the land planning work of the Bureau of Land Management (BLM) and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the U.S. Geological Survey under contract number 14-08-0001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (P.L. 94-377). Published and unpublished public information available through September, 1978, was used as the data base for this study. No new drilling or field mapping was performed as part of this study, nor was any confidential data used.

Location

The Milner quadrangle is located in central Routt County in northwestern Colorado, approximately 10 miles (16 km) west of the town of Steamboat Springs and 25 miles (40 km) east of the town of Craig via U.S. Highway 40. The town of Milner is located in the northeastern corner of the quadrangle. The sites of Coal View and Bear River, abandoned coal camps, are located in the northwestern part of the quadrangle.

Accessibility

U.S. Highway 40 crosses the northern part of the Milner quadrangle from east to west connecting Steamboat Springs to the east of the quadrangle with the town of Hayden approximately 8 miles (13 km) to the west. A paved medium-duty road cuts the extreme southwestern corner of the quadrangle connecting U.S. Highway 40 to the northwest with the town of Oak Creek to the southeast. Numerous unimproved dirt roads and trails provide access for the remainder of the quadrangle.

Railway service for the Milner quadrangle is provided by the Denver and Rio Grande Western Railroad from Denver to the railhead at Craig. The railroad passes through the Yampa River valley in the northern part of the quadrangle, and serves as the major transportation route for coal shipped east from northwestern Colorado. A spur from this line extends south along Fish Creek in the southeastern corner of the quadrangle (U.S. Bureau of Land Management, 1977).

Physiography

The Milner quadrangle lies in the southern part of the Wyoming Basin physiographic province as defined by Howard and Williams (1972). The quadrangle is approximately 10 miles (16 km) east of the Williams Fork Mountains and approximately 17 miles (27 km) west of the Park Range, which forms the Continental Divide in northwestern Colorado. The landscape of the northwestern half of the quadrangle is characterized by steep slopes dissected by narrow gulches. The northern part of the quadrangle is cut by the Yampa River valley which ranges in width from approximately 0.3 to 1.3 miles (0.5 to 2.1 km). Twentymile Park, in the southeastern half of the quadrangle, is characterized by gentle slopes and meandering creeks.

Approximately 1,660 feet (506 m) of relief is present in the Milner quadrangle. Altitudes range from 8,106 feet (2,471 m) on a peak in the west-central part of the quadrangle to less than 6,440 feet (1,963 m) along the Yampa River in the northwest corner of the quadrangle.

The Milner quadrangle is drained by the Yampa River, which flows from east to west across the northern part of the quadrangle, and by several creeks and intermittent streams which are tributaries of the Yampa. Fish Creek and Foidel Creek drain the southern half of the quadrangle and flow northeastward into Trout Creek, a tributary of the Yampa River. Elk Creek also flows northeastward into Trout Creek.

Tow Creek and Cheney Creek, as well as several intermittent streams, drain the northern part of the quadrangle and flow southward directly into the Yampa River.

Climate and Vegetation

The climate of northwestern Colorado is semiarid. Clear, sunny days prevail in the Milner quadrangle area, with daily temperatures typically varying from 0° to 35°F (-18° to 2°C) in January and from 42° to 80°F (6° to 27°C) in July. Annual precipitation in the Milner area averages 18 inches (45 cm), most of which occurs as snowfall during the winter months. Winds, averaging 3 miles per hour (4.8 km per hour), are generally from the west, but wind directions and velocities vary greatly depending on the local terrain (U.S. Bureau of Land Management, 1977).

Mountain shrub, including serviceberry, Gambel oak and rabbitbrush, is the typical vegetation present at higher altitudes in the Milner quadrangle. Sagebrush dominates the lower slopes in the quadrangle, while some areas along Fish Creek and the Yampa River are utilized as cropland. Cottonwood, willows, and grasses are also present along the Yampa River (U.S. Bureau of Land Management, 1977).

Land Status

The Milner quadrangle lies along the eastern edge of the Yampa Known Recoverable Coal Resource Area (KRCRA). Approximately 75 percent of the quadrangle lies within the KRCRA boundary and the Federal government owns approximately 10 percent of the coal rights in this area. Two active coal leases are present within the KRCRA boundary as shown on plate 2.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area of the Milner quadrangle was reported by Emmons (1877) as part of a survey of the fortieth parallel. The decision to build a railroad into the region

stimulated several investigations of coal between 1886 and 1905, including papers by Hewett (1889), Hills (1893), Storrs (1902), and Parsons and Liddell (1903). Fenneman and Gale (1906) prepared a geologic report on the Yampa Coal Field including a description of the geology and occurrence of coal in the Milner quadrangle. Campbell (1923) described the Twentymile Park district of the Yampa coal field. In 1955, Bass and others expanded Fenneman and Gale's work in a report on the geology and mineral fuels of parts of Routt and Moffat Counties and this is the most comprehensive work on the area. Tweto (1976) compiled a generalized regional geologic map which included this quadrangle. Reconnaissance drilling in the Yampa coal field by the U.S. Geological Survey was reported by Brownfield (1978).

Stratigraphy

Rock formations cropping out in this quadrangle are all late Cretaceous in age and include the Mancos, Iles, Williams Fork, and Lewis Shale. Only the Iles and Wiliams Fork Formations of the Mesaverde Group are known to contain coal.

The Mancos Shale crops out along the axis of the Tow Creek anticline in the north-central part of the quadrangle. It consists of a thick sequence of gray to dark-gray shale with a number of tan silty sandstones interbedded with sandy shale and shale in the upper 1,000 feet (305 m) of the formation. The sandstones are thin-bedded and ledge-forming, each 40 to 75 feet (12 to 23 m) or more thick (Bass and others, 1955). The total thickness of this formation is not known in this quadrangle, but Bass and others (1955) indicate that it is about 4,900 feet (1,494 m) thick in the area they mapped.

The Mesaverde Group conformably overlies the Mancos Shale and consists of two coal-bearing formations, the Iles and the Williams Fork.

The Iles Formation is approximately 1,500 feet (457 m) thick and crops out over a wide area on the flanks of the Tow Creek anticline and

the Twentymile Park syncline in the northwestern and northeastern parts of the quadrangle, respectively. The Iles Formation consists of the basal Tow Creek Sandstone Member, an overlying sequence of sandstones interbedded with sandy shale, shale, and coal, and at the top of the formation, the Trout Creek Sandstone Member (Bass and others, 1955).

The Tow Creek Sandstone Member is a light-brown fine-grained massive cliff-forming sandstone ranging in thickness from approximately 50 to 85 feet (15 to 26 m) where measured in the oil wells drilled in the quadrangle. It forms a prominent ledge capping the slopes on both sides of the Tow Creek anticline in the Milner quadrangle. The Tow Creek Sandstone Member is overlain by light-brown, light-gray, and white massive ledge-forming sandstones interbedded with gray sandy shale, shale, and coal. The coal, designated as the Lower Coal Group by Fenneman and Gale (1906), is distributed throughout the middle and upper parts of the Iles Formation. This sequence is capped by the Trout Creek Sandstone Member, a white fine-grained massive cliff-forming sandstone, approximately 100 feet (30 m) thick (Bass and others, 1955).

The Williams Fork Formation conformably overlies the Iles Formation and crops out in a broad band along the flanks of the Tow Creek anticline and the Twentymile Park syncline in the southwestern, central, and southeastern parts of the quadrangle (Bass and others, 1955). It is approximately 1,100 to 1,300 feet (335 to 396 m) thick and is divided into four units by Ryer (1977): a lower coal-bearing member, a marine shale member, the Twentymile Sandstone Member, and an upper member.

The lower coal-bearing member is designated as the Middle Coal Group (Fenneman and Gale, 1906), and contains approximately 300 feet (91 m) of interbedded medium- to dark-gray siltstone, silty sandstone, very fine grained tan to gray sandstone, and coal (Ryer, 1977). Two major coal beds, the Wolf Creek and the Wadge, occur in the Middle Coal Group. They are stratigraphically located approximately 45 feet (14 m) and 210 feet (64 m), respectively, above the Trout Creek Sandstone Member. The overlying marine shale sequence, which is approximately 650

feet (198 m) thick in the Milner quadrangle, is composed of dark-gray to dark-tan shale, silty shale and tan siltstone which grades upward into the overlying Twentymile Sandstone Member (Ryer, 1977). The Twentymile Sandstone Member, which ranges in thickness from 100 to 120 feet (30 to 37 m) in the Milner quadrangle, is a massive white ledge-forming sandstone (Bass and others, 1955; Ryer, 1977). A well-defined contact exists between the Twentymile Sandstone Member and the overlying upper member. The upper member is composed of sandstone, sandy shale, dark-gray shale, and a few local coals (Bass and others, 1955) and is estimated to be between 200 and 250 feet (61 and 76 m) thick in the Milner quadrangle. The local coals are designated as the Upper Coal Group (Fenneman and Gale, 1906).

The non-coal-bearing Lewis Shale conformably overlies the Williams Fork Formation in the Milner quadrangle and consists of a homogeneous dark-gray to bluish marine shale. It crops out in a broad area in the south-central part of the quadrangle along the axis of the Twentymile Park syncline (Bass and others, 1955).

The formations exposed in the Milner quadrangle accumulated close to the western edge of a Late Cretaceous-age epeirogenic seaway which covered part of the western interior of North America. Several transgressive-regressive cycles resulted in the deposition of a series of offshore-marine, shallow-marine, and marginal-marine sediments in the Milner area (Ryer, 1977). During the deposition of the Iles and Williams Fork Formations, near-shore marine, littoral, brackish tidal, brackish and fresh-water supratidal, and fluvial environments existed in northwestern Colorado. The interbedded sandstones, shales, and coals of the two formations were deposited as a result of minor changes in position of the shoreline (Konishi, 1959; Kucera, 1959).

Coals with wide areal extent were deposited near the seaward margins of non-marine environments, probably in large brackish-water lagoons or swamps. The slow migration of this depositional environment is responsible for the wide areal extent of the Wadge and Wolf Creek coal

beds in the Yampa study area. Coals of limited areal extent were generally deposited in environments associated with fluvial systems such as back-levee and coastal plain swamps, interchannel basin areas, and abandoned channels. The major sandstones of the Iles and Williams Fork Formations were deposited in shallow marine and near-shore environments. Subsequent deposition of the marine Lewis Shale marked a landward movement of the sea, and the end of near-shore and continental sedimentation of the Mesaverde Group in the Milner quadrangle area (Konishi, 1959; Kucera, 1959).

Structure

Two major structures, the Tow Creek anticline and the Twentymile Park syncline, occur in the Milner quadrangle and both plunge to the south. The axis of the Tow Creek anticline runs north-northeasterly across the southwestern and north-central parts of the quadrangle. The Twentymile Park syncline extends northward from the south-central part of the quadrangle into the northeastern quarter of the quadrangle just west of the town of Milner (Bass and others, 1955). Coal bed dips are generally between 5° and 25° on the flanks of these structures. However dips approach 35° towards the east on the eastern limb of the Tow Creek anticline (the western limb of the Twentymile Park syncline). The northern half of the quadrangle contains several northwest-southeast-trending high angle faults (Bass and others, 1955).

Structure contour maps of the isopached coal beds are based on a regional structure contour map of the top of the Trout Creek Sandstone Member by Bass and others (1955), and it is assumed that the structure of the coal beds duplicates that of the Trout Creek Sandstone Member. Modifications were made where necessary in accordance with outcrop and drill hole data.

Drill holes or measured sections from which the elevation of the top of the coal beds could not be determined are not shown on the structure maps and were not used as data points in map construction.

COAL GEOLOGY

Coal beds in the Lower, Middle, and Upper Coal Groups (Fenneman and Gale, 1906) of the Mesaverde Group have been identified in this quadrangle. The Lower Coal Group includes the coal beds in the Iles Formation, and the Middle Coal Group includes the coal beds between the Trout Creek and Twentymile Sandstone Members in the lower coal-bearing zone of the Williams Fork Formation. The Upper Coal Group includes the coal beds above the Twentymile Sandstone Member extending up to the base of the Lewis Shale. In the Milner quadrangle, coal beds in the Lower and Upper Groups are characteristically lenticular and of limited areal extent while coal beds of the Middle Group persist over a large area.

In this report, coal beds that exceed Reserve Base thickness (5.0 feet or 1.5 meters) which are not formally named have been numbered with bracketed numbers for identification purposes in this quadrangle only.

Dotted lines shown on some of the derivative maps represent a limit of confidence beyond which isopach, structure contour, overburden isopach, and areal distribution and identified resources maps are not drawn because of insufficient data, although it is believed that the coal beds may continue to be greater than Reserve Base thickness beyond the dotted lines.

Chemical analyses of coal.--Analyses of the coals in this area are listed in table 1. In general, chemical analyses of coals in the Lower and Middle Coal Groups indicate that these coals are high-volatile C bituminous in rank on a moist, mineral-matter-free basis according to ASTM Standard Specification D 388-77 (American Society for Testing and Materials, 1977).

Locations of coal samples tested in this quadrangle are listed in table 1 and include those for the Bear River coal bed of the Lower Coal Group and the Wolf Creek and Wadge coal beds of the Middle Coal Group. Chemical analyses were not available for each bed in the Lower and Middle Coal Groups. However, the analyses shown in the table are believed to be representative of all Lower and Middle Group coals.

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Lower Coal Group

The Lower Coal Group includes the coal beds of the Iles Formation. Bass and others (1955) identified three coal zones in the Lower Coal Group. Coal beds which belong to zone 1 have not been identified in the quadrangle. Because there does not seem to be a thick non-coal-bearing interval between zones 2 and 3 in this quadrangle as there is in other areas, the zones have been arbitrarily divided by using the Bear River coal bed as the base of zone 3. Accordingly, all coal beds below the Bear River coal bed are assigned to zone 2, and zone 3 includes the Bear River coal bed and all coals above it in the Iles Formation.

In addition to the Bear River coal bed, numerous thin, lenticular coal beds of the Lower Coal Group have been identified in the Milner quadrangle, but only four of these beds are greater than Reserve Base thickness (5.0 feet or 1.5 meters) where they occur on Federal coal land. These beds are designated LG2[1] (i.e., Lower Coal Group, zone 2,. coal bed [1]), LG2[4], LG3[6], and LG3[8]. The LG2[4] coal bed is mapped as a local bed in this report. Because each of the other beds has been measured at only one location they have been treated as isolated data points (see Isolated Data Points section of this report).

LG2[4] Coal Bed

The LG2[4] coal bed was penetrated in four drill holes in the west-central part of the quadrangle as shown in figure 1. The coal bed ranges in thickness from 3.0 to 6.0 feet (0.9 to 1.8 m), having its maximum recorded thickness in sec. 35, T. 6 N., R. 87 W. Overburden thickness increases to the west (figure 2) and the coal bed is cut by a west-northwest-trending fault (Bass and others, 1955).

Bear River Coal Bed

The Bear River coal bed is located about 600 feet (183 m) stratigraphically below the top of the Trout Creek Sandstone Member and was named after the coal camp of Bear River. This coal bed has been mined previously in several small strip and underground mines near the northwestern edge of the quadrangle where it has also been identified in several drill holes.

Measured thicknesses of the Bear River coal bed (plate 4) range from 2.0 to 12.0 feet (0.6 to 3.7 m). Near the Allen and Rustic Mines in sec. 34, T. 6 N., R. 87 W., the coal bed contains numerous thin partings ranging from 0.2 to 2.0 feet (0.1 to 0.6 m) in thickness. At the Bear River Mine in sec. 11, T. 6 N., R. 87 W., the coal bed is 9.3 feet (2.8 m) thick with no recorded partings.

Middle Coal Group

Coal beds in the Middle Coal Group are located between the top of the Trout Creek Sandstone Member of the Iles Formation and the base of the Twentymile Sandstone Member of the Williams Fork Formation. The Middle Coal Group includes the Wolf Creek, the Wadge, and the Lennox coal beds which occur, stratigraphically, approximately 45 feet (14 m), 210 feet (64 m) and 240 feet (73 m), respectively, above the base of the Williams Fork Formation. These coal beds are known to persist over a large area.

Wolf Creek Coal Bed

The Wolf Creek coal bed, located approximately 45 feet (14 m) stratigraphically above the base of the Williams Fork Formation, has been mined in several small underground mines and identified in outcrops and in drill holes in the north-central and eastern parts of the Milner quadrangle (plate 8). The coal bed ranges in thickness from 7.9 to 13.0 feet (2.4 and 4.0 m) where measured in the quadrangle and locally contains shale partings 0.2 to 1.0 feet (0.06 to 0.3 m) thick. Isopachs of the Wolf Creek coal bed have been projected into this quadrangle based on geologic data from the adjacent Mount Harris, Hooker Mountain, and Wolf Mountain quadrangles to the west, northwest, and north, respecitvely. It is believed that the coal bed may be as much as 19 feet (5.8 m) thick at the west-central edge of the quadrangle.

Wadge Coal Bed

The Wadge coal bed is known to persist over most of the eastern part of the Yampa KRCRA. The coal bed lies approximately 165 feet

(50 m) above the top of the Wolf Creek coal bed and 210 feet (64 m) above the base of the Williams Fork Formation. The Wadge coal bed has been mined at the Seneca No. 2 strip mine along the northwestern edge of the quadrangle and at the Osage and MacGregor strip mines in the north-central part of the quadrangle. It has also been mined in several small underground mines and has been identified in outcrops and drill holes in the north-central and eastern parts of the Milner quadrangle.

Measurements of the Wadge coal bed in the quadrangle range from 6.0 to 11.0 feet (1.8 to 3.4 m) in thickness. The coal bed locally contains shale partings 0.1 to 0.8 feet (0.03 to 0.2 m) thick. Similar to the Wolf Creek coal bed, the Wadge coal bed has been projected into the western edge of this quadrangle based on geologic data in the adjacent Mount Harris quadrangle and may be up to 12 feet (3.7 m) thick.

Lennox Coal Bed

The Lennox coal bed lies approximately 30 feet (9 m) stratigraphically above the Wadge coal bed. This coal bed is not known to be of Reserve Base thickness in this quadrangle, but it is worthy of note because the coal bed has been mined in some areas in conjunction with the principal Wadge coal bed.

Upper Coal Group

The Upper Coal Group includes all coal beds above the Twentymile Sandstone Member in the upper coal-bearing zone of the Williams Fork Formation. In the Milner quadrangle, the Upper Coal Group contains thin local coals including the Fish Creek coal bed which has been identified in a small underground mine and in outcrop along the eastern edge of the quadrangle. Upper Group coal beds, including the Fish Creek coal bed, are not known to exceed Reserve Base thickness in the Milner quadrangle.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 5 feet (1.5 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden

isopach maps are not available. The lack of data concerning these beds limits the extent they can be reasonably projected in any direction and usually precludes correlations with other, better known beds. For this reason, isolated data points are included on a separate sheet (in U.S. Geological Survey files) for non-isopached coal beds. Also, where the inferred limit of influence from the isolated data point is entirely within non-Federal land areas, isolated data point maps are not constructed for the coal bed. Descriptions and Reserve Base tonnages for the isolated data points occurring in this quadrangle and the influences from isolated data points in adjacent quadrangles are listed in table 5.

COAL RESOURCES

Data from drill holes, oil and gas wells, mine measured sections, and outcrop measurements (Bass and others, 1955; U.S. Geological Survey, 1933, 1936, 1938, 1958, 1963a, 1963b, 1969; and Brownfield, 1978) were used to construct outcrop, isopach, and structure contour maps of the coal beds in this quadrangle. The source of each indexed data point shown on plate 1 is listed in table 6.

Coal resources were calculated using data obtained from the coal isopach maps (plates 4, 8, and 12) and isolated data point maps. The coal bed acreage (measured by planimeter) multiplied by the average isopached thickness of the coal bed, and by a conversion factor of 1,800 short tons of coal per acre-foot (13,238 metric tons per hectare-meter) for bituminous coal, yields the coal resources in short tons (metric tons) for each isopached coal bed. Coal beds of Reserve Base thickness (5.0 feet or 1.5 meters) or greater that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ from those used in calculating Reserve Base and Reserve tonnages as stated in U.S. Geological Survey Bulletin 1450-B, which are a minimum thickness of 28 inches (70 cm) and a maximum depth of 1,000 feet (305 m) for bituminous coal.

Reserve Base and Reserve tonnages for the isopached coal beds are shown on plates 7, 11, and 15, and are rounded to the nearest 10,000

short tons (9,072 metric tons). Only Reserve Base tonnages (designated as inferred resources) are calculated for isolated data points. Coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 36.08 million short tons (32.73 million metric tons) for the entire quadrangle, including tonnages from the isolated data points.

Dames & Moore has not made any determination of economic recoverability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn to coincide with the boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 200 feet (61 m) or less of overburden were considered to have potential for surface mining and can be assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is shown on the following page:

$$MR = \frac{t_o\ (cf)}{t_c\ (rf)}$$

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

cf = conversion factor to yield MR value in terms of cubic yards of overburden per short tons of recoverable coal:
0.911 for subbituminous coal
0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey.

Areas where the coal data is absent or extremely limited between the 200-foot (61-m) overburden line and the outcrop are assigned unknown development potentials for surface mining methods. This applies to areas where coal beds 5.0 feet (1.5 m) or more thick are not known, but may occur, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds in these areas prevents accurate evaluation of the development potential in the high, moderate, or low categories. The area influenced by the isolated data points in this quadrangle contain approximately 1.83 million short tons (1.66 million metric tons) of coal available for surface mining.

The coal development potential for surface mining methods is shown on plate 6. Of the Federal land areas having a known development

potential for surface mining methods within the KRCRA in this quadrangle, 90 percent are rated high, 5 percent are rated moderate, and 5 percent are rated low. The remaining non-leased Federal lands within the KRCRA boundary are classified as having unknown development potential for surface mining methods. Reserve Base tonnages in the various development potential categories for surface mining methods are listed in table 2.

Development Potential for Subsurface and In-Situ Mining Methods

Areas considered to have a development potential for conventional subsurface mining methods include those areas where coal beds of Reserve Base thickness are between 200 and 3,000 feet (61 and 914 m) below the ground surface and have dips of 15° or less. Unfaulted coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Areas of high, moderate, and low development potential for conventional subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 200 to 1,000 feet (61 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m), respectively.

Areas where the coal data is absent or extremely limited between 200 and 3,000 feet (61 and 914 m) below the ground surface are assigned unknown development potentials. This applies to the areas influenced by isolated data points and to those areas where coal beds of Reserve Base thickness are not known, but may occur. The areas influenced by isolated data points in this quadrangle contain approximately 1.11 million short tons (1.01 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining methods is shown on plate 17. All of the non-leased Federal land areas having a known development potential for conventional subsurface mining methods are rated high. The remaining Federal lands within the KRCRA

boundary are classified as having unknown development potentials for conventional subsurface mining methods. Reserve Base tonnages in the varous develoment potential categories for subsurface mining methods are listed in table 3.

Based on criteria provided by the U.S. Geological Survey, coal beds of Reserve Base thickness dipping between 35° and 90° with a minimum Reserve Base of 50 million short tons (45.4 million metric tons) for bituminous coal and 70 million short tons (63.5 million metric tons) for subbituminous coal have a moderate potential for in-situ development; coal beds dipping from 15° to 35°, regardless of tonnage, and coal beds dipping from 35° to 90° with less than 50 million short tons (45.4 million metric tons) of coal have a low development potential for in-situ mining methods. Coal lying between the 200-foot (61 m) overburden line and the outcrop is not included in the total coal tonnages available as it is needed for cover and containment in the in-situ process.

Areas where faulted coal beds of Reserve Base thickness dip greater than 15° between 200 and 3,000 feet (61 and 914 m) below the ground surface are classified as having an unknown development potential for in-situ mining methods. These criteria also apply to those areas influenced by isolated data points where the coal beds dip greater than 15° and are not faulted. The areas influenced by isolated data points in this quadrangle contain approximately 0.62 million short tons (0.56 million metric tons) of coal available for in-situ mining.

Coal development potential for in-situ mining methods is shown on plate 17. All of the Federal land areas classified as having known development potential for in-situ mining methods are rated low. The remaining Federal lands within the KRCRA boundary are classified as having unknown development potential for in-situ mining methods. Reserve Base tonnages in the various development potential categories for in-situ mining methods are listed in table 4.

Table 1. -- Chemical analyses of coals in the Milner quadrangle, Routt County, Colorado.

Location	COAL BED NAME	Form of Analysis	Proximate				Ultimate					Heating Value	
			Moisture	Volatile Matter	Fixed Carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/Lb
Secs. 20, 21, 27, 28, T. 6 N., R. 86 W., Osage Mine (Aresco and others, 1958)	Wadge	A	10.9	41.8	51.6	6.6	0.5	-	-	-	-	-	11,300
		A	11.0	41.7	51.5	6.8	0.5	-	-	-	-	-	11,290
S½ NW¼ sec. 35, T. 6 N., R. 87 W., Seneca Strip No. 2 Mine (Boreck and others, 1977)	Wadge	A	8.0	36.6	46.0	9.4	0.5	-	-	-	-	-	11,130
		B	-	39.8	50.0	10.2	0.6	-	-	-	-	-	12,090
		C	-	44.3	55.7	-	0.6	-	-	-	-	-	13,460
SE¼ sec. 21, T. 6 N., R. 86 W., Elk Creek Mining Co. Mine (Campbell, 1923)	Wolf Creek	A	12.1	34.6	41.9	11.4	0.46	-	-	-	-	-	10,200
		B	-	39.4	47.6	13.0	0.52	-	-	-	-	-	11,610
		C	-	45.3	54.7	-	0.60	-	-	-	-	-	13,340
SW¼ sec. 11, T. 6 N., R. 87 W., Bear River Coal Co. Mine No. 1 (Bass and others, 1955)	Bear Creek	A	10.5	37.4	47.1	5.0	0.5	-	-	-	-	-	11,730
		B	7.4	38.7	48.7	5.2	0.5	-	-	-	-	-	12,120
		C	-	41.8	52.6	5.6	0.6	-	-	-	-	-	13,100

Form of Analysis: A, as received
B, air dried
C, moisture free

Note: To convert Btu/pound to kilojoules/kilogram, multiply by 2.326

Table 2. -- Coal Reserve Base data for surface mining methods for Federal coal lands (in short tons) in the Milner quadrangle, Routt County, Colorado.

Coal Bed or Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Wadge	1,470,000	450,000	640,000	-	2,560,000
Wolf Creek	5,810,000	1,780,000	1,320,000	-	8,910,000
Bear River	280,000	150,000	1,230,000	-	1,660,000
Isolated Data Points	-	-	-	1,830,000	1,830,000
Totals	7,560,000	2,380,000	3,190,000	1,830,000	14,960,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 3. -- Coal Reserve Base data for subsurface mining methods for Federal coal lands (in short tons) in the Milner quadrangle, Routt County, Colorado.

Coal Bed	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Wadge	3,990,000	310,000	-	-	4,300,000
Wolf Creek	4,200,000	2,570,000	-	-	6,770,000
Bear River	880,000	-	-	-	880,000
Isolated Data Points	-	-	-	1,110,000	1,110,000
Totals	9,070,000	2,880,000	-	1,110,000	13,060,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 4. -- Coal Reserve Base data for in-situ mining methods for Federal coal lands (in short tons) in the Milner quadrangle, Routt County, Colorado.

Coal Bed	Moderate Development Potential	Low Development Potential	Unknown Development Potential	Total
Wadge	-	2,830,000	-	2,830,000
Wolf Creek	-	4,610,000	-	4,610,000
Bear River	-	-	-	-
Isolated Data Points	-	-	620,000	620,000
Totals	-	7,440,000	620,000	8,060,000

NOTE: To convert short tons to metric tons, multiply by 0.9072.

Table 5.--Descriptions and Reserve Base tonnages (in million short tons) for isolated data points

Coal Bed	Source	Location	Thickness	Reserve Base Tonnages		
				Surface	Subsurface	In-Situ
LG2[1]	Kingwood Oil Co.	sec. 31, T. 6 N., R. 86 W.	6.0 ft (1.8 m)	0	0.18	0
LG3[6]	Bass and others (1955)	sec. 8, T. 6 N., R. 86 W.	5.0+ ft (1.5+ m)	0.33	0.50	0.35
LG3[8]	Bass and others (1955)	sec. 8, T. 6 N., R. 86 W.	5.1 ft (1.5 m)	1.50	0.41	0.27
		From Hooker Mountain Quadrangle				
MG[2]	Bass and others (1955);	sec. 3, T. 6 N., R. 87 W.	5.1 ft (1.5 m)	0	0.02	0

NOTE: To convert short tons to metric tons, multiply by 0 9072.

Table 6. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	U.S. Geological Survey, 1963a, Inactive Coal Prospecting Permit No. Colorado 045129, Pittsburg & Midway Coal Co.	Drill hole No. MC-8
2	↓	Drill hole No. MC-9
3	↓	Drill hole No. MC-11
4	↓	Drill hole No. MC-10
5	↓	Drill hole No. MC-4
6	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 23	Measured Section
7	U.S. Geological Survey, 1963a, Inactive Coal Prospecting Permit No. Colorado 045129, Pittsburg & Midway Coal Co.	Drill hole No. MC-3
8	↓	Drill hole No. MC-5
9	↓	Drill hole No. MC-6
10	↓	Drill hole No. MC-7
11	Bass, and others, 1955, U.S. Geoloigcal Survey Bulletin 1027-D, pl. 25 pl. 25	Measured Section No. B-139A
12	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl 23	Measured Section No. B-88
13	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Mine Measured Section No. B-117a
14	↓	Mine Measured No. B-124a
15	↓	Measured Section No. B-117
16	↓	Measured Section No. B-116

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
17	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl 25	Mine Measured B-118
18	↓	Measured Section No. B-120
19	Bass, (no date), U.S. Geological Survey, unpublished field notes	Unnumbered Drill Hole
20	Bass, and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Mine Measured Section No. B-122
21	↓	Mine Measured Section No. B-122a
22	↓	Mine Measured Section No. B-123
23	↓	Mine Measured Section No. B-124-125
24	↓	Mine Measured Section No. B-126-127
25	↓	Measured Section No. B-128
26	↓	Measured Section No. B-130
27	↓	Measured Section B-131
28	↓	Mine Measured Section No. B-129
29	↓	Mine Measured Section No. B-132
30	↓	Mine Measured Section No. B-135

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
31	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. B-134
32	↓	Mine Measured Section No. B-136
33		Mine Measured Section No. B-137
34		Mine Measured Section No. B-138 and B-139
35		Mine Measured Section No. B-170
36		Mine Measured Section No. B-172
37	U.S. Geological Survey, 1938, Inactive Coal Lease No. Denver 043176, Pinnacle Coal Co. and 1963b, Inactive Coal Lease No. Denver 052419, J. W. Winters and J. B. Hottel	Mine Measured Section
38	U.S. Geological Survey, 1938, Inactive Coal Lease No. Denver 043176, Pinnacle Coal Co.	Mine Measured Section
39	U.S. Geological Survey, 1933, Inactive Coal Prospecting Permit No. Denver 040965, Celeste Zulian	Mine Measured Section
40	↓	Mine Measured Section
41	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Mine Measured Section No. B-171
42	↓	Mine Measured Section No. B-171a

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
43	U.S. Geological Survey, 1933, Inactive Coal Prospecting Permit No. Denver 040965, Celeste Zulian	Drill hole
44	U.S. Geological Survey, 1936, Inactive Coal License No. Denver 047218, Celeste Zulian	Mine Measured Section
45	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl 25	Mine Measured Section No. B-173
46	↓	Mine Measured Section No. B-182
47	Pubco Petroleum Corp.	Oil/gas well No. 1 Grassy Creek Coal Co.
48	Bass and others, 1955, U.S. Geological Survey Bulletin 1027-D, pl. 25	Measured Section No. B-193
49	U.S. Geological Survey, 1958, Inactive Coal Lease No. Denver 032654, Colorado and Utah Coal. Co.	Drill hole No. HM-8
50	Mesa Petroleum Co.	Oil/gas well No. 2 Grassy Creek Coal Co.
51	Ken D. Luff, Inc.	Oil/gas well No. 11-Gov't Grassy Creek
52	Kingwood Oil Co.	Oil/gas well No. 1-A State
53	Luff-Martinets-Alpine	Oil/gas well No. 3 Grassy Creek Coal Co.
54	Energy Reserves Group, Inc.	Oil/gas well No. 1 John Eilts

Table 6. -- Continued

Plate 1 Index Number	Source	Data Base
55	Luff-Martinets-Alpine	Oil/gas well No. 2 Grassy Creek Coal Co.
56	Kingwood Oil Co.	Oil/gas well No. 1-State Grassy Creek
57	Clinton Oil Co.	Oil/gas well No. 1 Grassy Creek Coal Co.
58	Brownfield, 1978, U.S. Geological Survey Open-File Report 78-365	Drill hole No. M-3
59	↓	Drill hole No. M-4
60	↓	Drill hole No. M-5
61	Schneider, 1978, U.S. Geological Survey Open-File Report 78-848	Drill hole No. DH-1
62	↓	Drill hole No. DH-4

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